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Integrated Management of the Mediterranean Fruit Fly *(Ceratitis capitata)* on Citrus in the Konispol, Albania

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Abstract

The Mediterranean fruit fly (*Ceratitis capitata*) is the main pest of citrus fruits, which can also infect other economically priority fruit plant species in an integrated global environment. Numerous populations of this insect contribute to the spread of fungi and microbes that cause secondary damage, such as fruit rot. Infestation of citrus orchards can lead to significant annual losses in crop size and quality. As a quarantine pest with high reproductive potential and spreading ability, the Mediterranean fruit fly is difficult to control and poses a serious threat to Albanian citrus exports due to concerns about infection or insecticide residues. The purpose of this study was to investigate the current state of integrated management of the Mediterranean fruit fly on citrus plants in the Konispol region, using innovative approaches. As part of this objective, the dynamics of the Mediterranean fruit fly population were studied using Trimedlure bait traps. The potential of organic integrated agricultural fruit production in the aspect of pest control was analysed. Integrated pest control programmes were described in detail, including a range of modern, safe population control methods and positioned as innovative, effective strategies for controlling the Mediterranean fruit fly. The study analysed the potential of modern tools and technologies for pest control. The areas of minimising the share of chemical protective equipment in the agricultural management system were outlined. As a result of the experiment, the effectiveness of the technique of mass trapping of pests was established. Comparative analysis of monitoring results at different farm plots was carried out. Based on the obtained data, the potential of management and technological measures to minimise the load on citrus plantations, combining the principles of environmental safety and economic feasibility, with the introduction of the latest systems for controlling and monitoring pest populations, was analysed.

Keywords

Population ccontrol; Pests; Pesticides; Level of destruction; Impact factor; Ecosystem Approach

Introduction

Recent estimate of the number of host plants or potential host plants of the Mediterranean fruit fly, *Ceratitis capitata*, identified 353 species. The host plants of the Mediterranean fruit fly grow in tropical, subtropical, and temperate climates on all five continents. Such high polyphagy and destructive ability of many types of fruits and vegetables make this pest a serious threat to agricultural production in many countries.

The problems of integrated management of the Mediterranean fruit fly on citrus plants and the development of measures to optimise industry programmes in the context of sustainable management are reflected in the papers by modern researchers. Azeem *et al.* (2022) are convinced of the feasibility of repeated insecticide treatments to reduce plant death and the need for strict quarantine treatments of fruits for export to countries free of this pest. Researchers suggest that control measures usually pollute plants and the environment and can increase the cost of agricultural production. Representatives of the modern scientific community, Mehta, Shyamrao and Raghuraman (2021), analysed the practical experience of optimising the control of Mediterranean fruit flies. Researchers suggest that the current system should be based on repeated spraying with organophosphate substances, up to 10 treatments per year. The effectiveness of the sterile insect technique (SIT) in eradicating this pest in some geographical regions is presented, highlighting recent advances in SIT methodology for controlling the Mediterranean fruit fly through the development of genetic sex lines that allow the release of only sterilised males.

Ismail *et al.* (2023) argue that the effectiveness of population assessment to accurately reflect changes caused by displacement, death, and reproduction is a prerequisite for the success of any pest control operation. SIT, in particular, requires effective and accurate methods for monitoring pest populations prior to the release of sterile insects, to monitor pest population decline during the release campaign, and to survey the area after destruction for any reintroduction of pests. Representatives of the modern scientific community, Venter, Baard and Barnes (2021), analysed practical experience in optimising the management paradigm in terms of convergence of basic principles and existing tools for regulating the Mediterranean fruit fly population in citrus production regions. Researchers paid special attention to the need to investigate natural and anthropogenic ecosystems in the concept of topical issues of preserving biological resources for sustainable regional development.

Smaili, Boutaleb-Joutei and Blenzar (2020) investigated the concepts of implementing monitoring policies as an aspect of integrated management at the regional level in developed countries. Adult fly surveillance is mainly carried out through traps that attract insects, usually through olfactory or visual stimulation. It is noted that many Mediterranean fruit fly trapping systems have been developed over the years, and variations in combining bait with appropriate means to catch flies as soon as they land are described. Most commonly used are sexual or food scents, fly-friendly colours, or a combination of both. Researchers are convinced that scents attract flies from long distances, while colours attract them from short distances, usually after reaching the host tree or a certain part of the tree crown.

The associated risks and challenges are investigated by Urbaneja *et al.* (2020), analysing basic solutions in the context of the concept under study. The researchers pay special attention to the problematic issues of comparing regional data. Since different trapping systems are often used in different countries or regions, it becomes difficult to compare data on the populations of these regions. In addition, population estimates made with the same trap, but in different climates, are difficult to compare. According to the researchers, given the cosmopolitan nature of the Mediterranean fruit fly and its control programmes over large areas, it is necessary to estimate or compare the levels of fly populations, even if they are measured by different traps and in different environments.

The best practices of modern researchers, in particular Pereira and Carvalho (1996), position monitoring as an important element in implementing optimal control measures for Mediterranean fruit fly populations. The researchers conducted several studies on trap models in Portuguese settings, which allowed them to gain more knowledge about the dynamics of the Mediterranean fruit fly population in citrus plantations. The study by the researchers is mainly concerned with assessing the population and subsequent harm intensity of the Mediterranean fruit fly, to provide specific and objective decision-making tools to improve intervention and management capabilities.

Tlemsani, Attia and Boulahia-Kheder (2022) examine the introduction of mass trapping by citrus producers, which is constrained by many factors, including the cost of traps, attractants, and labour. The purpose of the study was to minimise the cost of mass trapping by using inexpensive traps and reducing the density of traps, and to determine the feasibility of late and early trap installation. Researchers have proven the significant potential of mass trapping as an affordable and environmentally friendly technology, but at the same time, they have identified the need for further study on the use of trapping to improve the use of this tactic in the field. The basis of research in this area is the study by Baker and Chan (1991), which provides the basics for quantifying fruit fly dispersal, and population management based on safe methods.

These findings comprehensively characterise the problems, achievements, and current state of the integrated management system of the Mediterranean fruit fly on citrus plants. Despite their significance, the priority of promising areas for optimising environmental policy in the chosen area is not fully defined, and the issues of transformation of approaches to ensuring integrated management remain poorly investigated. The purpose of the study was to analyse the potential of integrated management of the Mediterranean fruit fly on citrus plants in the Konispol region using innovative approaches. Within the framework of this objective, the following tasks were set:

1. Investigation of the population dynamics of the Mediterranean fruit fly using Trimedlure bait traps.
2. Analysis of potential obstacles, risks, and challenges associated with the integrated pest population management process.

Materials and Methods

The task of investigating the population dynamics of the Mediterranean fruit fly using Trimedlure bait traps was conducted. Monitoring was carried out at regular intervals in traps to determine the appropriate time for intervention. The method of mass trapping

using attractive glue traps (Med Fly Stick) was used as an effective alternative to control for the preservation of the agroecosystem. The main research method was an experiment. The study was conducted in Konispol during 2019 on fields planted with citrus fruits, Clementine variety, with an area of 1 hectare. This village is located in the extreme southern part of Albania. The land on which the orchard was built had uniform fertility and water permeability. Experiments were conducted in citrus plantations that were in full production. This was an important element to guarantee the effectiveness of this method. The test site was 1 ha in size, with vegetation for several years, with the Clementine SA 63 variety and a planting distance of 5 m × 4 m. Field experiments were conducted in Konispol with two farmers, in Xarrë with two farmers, in Vrrin with one farmer, and in Mursi with one farmer.

To detect the presence of the pest in citrus plantations and to track the dynamics of its population, the female sex pheromones Trimedlure [t-butyl-2-methyl-4-chlorocyclohexanecarboxylate] were used as a significant factor in the introduction of the mass trapping method. This pheromone is a powerful attractant for detecting the first flights of the Mediterranean fruit fly and guarantees a successful monitoring programme. The trap used for monitoring was shaped like a wing trap covered with a plastic sheet. In the lower part there was a sticky tray on which the attractor was placed and, at the same time, insects were caught. Traction traps for monitoring were hung on branches at a height of 1-1.5 m in the crown of the tree. Attractants were considered as tools for controlling the Mediterranean fruit fly population (*Ceratitis capitata*). Mass capture is different from luring and killing. If pests remained inside the traction station, the technique was considered a mass catch. As for the placement of traps to implement the mass trapping technique, they were placed during the first 15 days of August, in the outer part of the crown and when the fruit was developed, but still green.

To do this, the authors used a glue trap (Med Fly Stick). The trap was in the form of a tube, which was covered with an adhesive material on the outside, at the end of which there was an attractant for Diptera (ammonium phosphate). The upper part was characterised by the presence of a special hook that helped to fix the device on the branches, and two small holes through which a specific scent was released. Attracted by the scent and yellow colour, the flies, instead of laying eggs on the fruit, were trapped and remained attached to the body of the tube. The trap was designed to catch flies before they lay their eggs. Due to its plastic composition, the trap was very strong and quite easy to use. The adhesive used can withstand temperatures up to 150°C. It was non-toxic, ready to use, and had the ability to catch for 3-4 months. In cases of high-intensity population dynamics, when the trap may be filled with flies several times and lose its ability to stick during cleaning, it can be replaced. The number of traps used in our experimental conditions was 50 traps/ha.

Another trap used in tests to control the Mediterranean fruit fly, *Ceratitis capitata*, using the mass trapping technique, was CeraTrap (Decis Trap). The Decis Trap used in experimental testing was a trap used in conventional and organic farms based on EU regulation 834/2007[1] (2007). The trap contained an attractant saturated with the

[1] Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. (2007). Available online at: eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0834 [accessed on 28 May 2024]

insecticide deltamethrin. After placing traps in citrus groves, flies were trapped and died due to contact with deltamethrin. The Decis Trap placement density was 80 traps/ha. The trap body consisted of a yellow plastic base and lid, and insecticide-soaked bait located inside the base. Flies entered through small holes and eventually died due to the action of the insecticide.

Results

The current progressive trend in the agri-food system is aimed at higher quality agricultural products in order to better meet the market requirements, which demands guaranteed products. In this context, the citrus sector is interested in continuously improving protection methods that allow achieving the goal of growing high-quality citrus fruits, with the possibility of avoiding increasing their cost and minimising the use of pesticides within the framework of food safety, as a constant requirement of EU standards.

The climatic conditions of Albania and citrus cultivation technologies have led to an unsatisfactory balance between citrus parasites and their natural enemies in the agroecosystem (Lopushnyak *et al.*, 2022). Under these conditions, the most problematic pest of the entire Mediterranean basin, the Mediterranean fruit fly, *Ceratitis capitata*, has already appeared with high dynamics. This pest has so far been controlled through the usual use of pesticides, which has led to the phenomenon of resistance to this pest and an increase in the level of chemical residues as a result of the use of pesticides outside biological criteria. To this end, protection programmes through the use of mass trapping methods require constant attention to avoid unnecessary chemical interventions, which, in addition to the risk to farmers and consumers, create serious problems due to disruption of the natural balance. The use of mass trapping techniques is the best way to achieve high-quality production and, at the same time, maximise the preservation of the environment. Parasite control is fully in line with the goal of increasing citrus production as an integral part of national and regional programmes aimed at achieving the main goals of Albanian Agricultural Competitiveness (AAC Lushnje) (Denysiuk *et al.*, 2022).

Mediterranean fruit fly *Ceratitis capitata* it is one of the most harmful insects in the world. Its population is able to tolerate cooler climates better than most other tropical fruit fly species. In Albania, the insect was first identified in the autumn of 1965 in Kamez. The larvae feed and develop on many deciduous, subtropical and tropical fruits, and some vegetables. Although the fly can be a major pest of citrus fruits, it often poses a very serious threat to some other fruits, such as peaches, pears, and apples. The larvae feed on the pulp of the host fruit, which eventually turns the fruit into a liquid inedible mass. This insect can infect more than 70 varieties of fruit trees. At the same time, citrus fruits – tangerine, lemon, orange, grapefruit, as well as peach, apple, pear, apricot – suffer the greatest harm. The insect infects the seeds of fruit trees at the end of summer, and citrus trees – in autumn. The larvae grow and develop inside the fruit, on the surface of which dark green softened spots appear. Fruits gradually rot and fall off. The Mediterranean fruit fly is characterised by the presence of reddish eyes; the reflex is blue. Transparent wings have 4 brown stripes; the belly is yellow. The body length is about 4.5-5 mm. The thorax has a black and white colour, with yellow spots (Figure 1).

Figure 1: Appearance of *Ceratitis capitata*
Source: (European and Mediterranean Plant Protection Organization, 2024)

The female is distinguished by the presence of ovipositors with sharp ends in the lower part of the abdomen. The larva is characterised by a white colour with yellow shades and a total length of up to 9 mm. The body is formed from 12 rings, the anus is chitinised and elongated. The pupa is light yellow-brown in colour, has an ovoid shape, and a total length of 4-5 mm. The insect under study is typical for countries with a warm climate, while the minimum thermal threshold for its active development is considered to be an average temperature of at least 13-14°C. The nature of climatic conditions determines the number of generations per year, the indicator of which varies in the range of 3-16. The most optimal conditions for the active development of the insect are a relative humidity of 70% and an average daily air temperature of 26°C. Females lay eggs under the skin of the fruit, at a rate of 4-6 eggs per day. A female can produce up to 800 eggs in a lifetime. Some types of fruit, such as apricots, apples, and pears suffer less damage than citrus fruits. However, when the Mediterranean fruit fly population is very numerous, females become less selective and infect less desirable host plants.

The embryonic stage of development is determined by air temperature indicators and lasts 2-25 days. Larvae, feeding on the pulp of the fruit, make burrows. After completing the full development cycle (9-50 days), the larvae leave the fruit and move to the soil. Pupate on the surface of the soil or in fruits (12-60 days). Flies that appear at the next stage of development feed on the juices of fruits and flowers. It is worth noting that the Mediterranean fruit fly at all stages of development shows high sensitivity to low air temperatures, in particular the indicator -2°C, is critical for the life of larvae. Considering such features, the affected fruits are placed in refrigerated rooms (-0.5° to +1°C) for 15-20 days. With such indicators of ambient temperature, the fruits of citrus fruits and other fruits do not lose their quality, but there are certain exceptions (apricot).

This pest is widespread in many countries of the world (Figure 2), it is attached to the lists of quarantine organisms of the South Cone Regional Phytosanitary Committee, the

European and Mediterranean Plant Protection Organisation, the International Regional Organisation for Plant and Animal Health, the Asia and Pacific Plant Protection Commission, and the Pacific Plant Protection Organisation (Pereira and Carvalho, 1996; European and Mediterranean Plant Protection Organization, 2024). Such attention to distribution of *Ceratitis capitata* indicates a significant phytosanitary risk posed by insect populations, and significant economic risks in the event of penetration and spread in new territories.

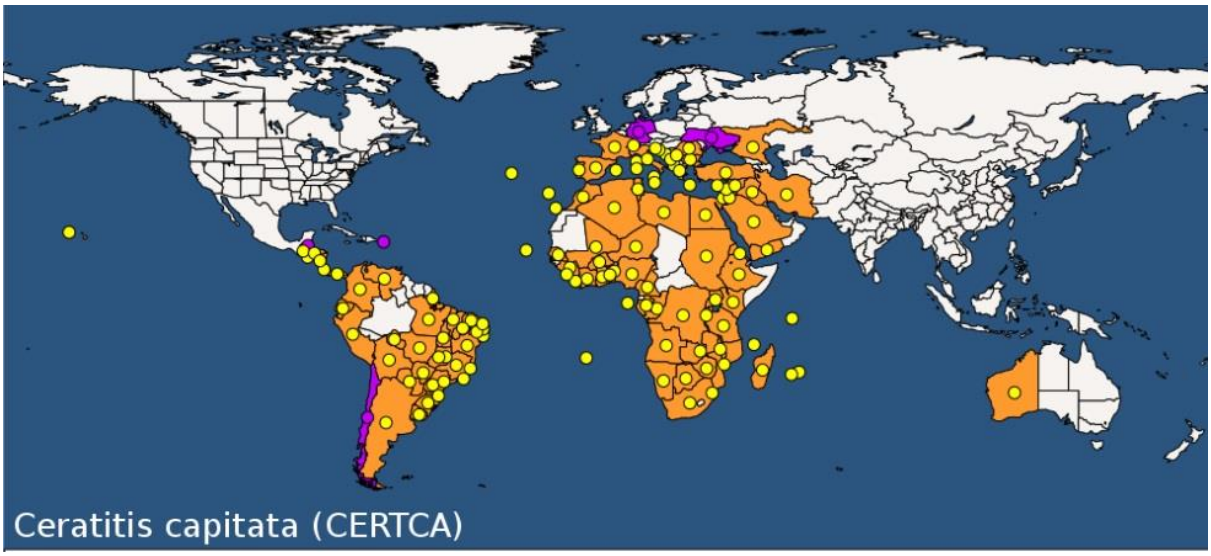

Figure 2: Distribution *of Ceratitis capitata*
Source: (European and Mediterranean Plant Protection Organization, 2024)

Integrated pest control (IPM) is a broad approach that includes a set of cost-effective pest control techniques. The UN structure responsible for agricultural safety defines it as a thorough analysis of all available pest control methods and the immediate inclusion of appropriate measures that prevent the development of pest populations, mass use of pesticides, and intervention at economically substantiated levels in case of environmental threats. The IPM concept is aimed at reducing or minimising risks to human health and the environment (Baker and Chan, 1991; European and Mediterranean Plant Protection Organization, 2024). Integrated pest control is seen in today's global environment as an effective and environmentally sensitive approach to pest control based on a combination of logical practices. Practical applications use up-to-date comprehensive information about the life cycles of pests and their interaction with the environment. This information, along with available pest control methods, is used to manage pest damage in the most economical way and with the lowest possible risk to people, property, and the environment.

The approach can be applied in both agricultural and non-agricultural settings, such as homes, gardens, and workplaces. The concept includes all relevant pest control options, including but not limited to the reasonable use of pesticides. Among the effective control methods, it is worth highlighting agrotechnical measures. Agrotechnical pest control services include the use of agrotechnical or horticultural methods that promote plant development and minimise the activity of pests and pathogens. By providing cultivation conditions that promote plant growth against the activity or development of insects and

pathogens, it becomes possible to avoid or minimise losses caused by pests (Panfilova *et al.,* 2019; Dankevych *et al.,* 2023). For open-ground cultivation and tillage operations are widely used to reduce soil compaction, increase water infiltration, increase the rate of decomposition of plant residues, change plant pathogen survival structures (Kicaj and Cobaj, 2023).

Using a balanced fertiliser application programme is another important requirement for healthy plant growth. Crop rotation is a simple but often effective means of controlling many pests (Costantino, 1930; Cayol and Causse, 1993). Practices such as the removal and destruction of infected plants or soil, the use of certified seeds free of pathogens or weeds, and the use of clean tools and equipment are essential to reduce the stock and spread of weeds, insects, and pathogens. The mechanical and physical control method continues to be used in integrated agriculture (for example, removing weeds manually or using tractor processing, controlling insects manually by removing the mass of their eggs and larvae) (Lyubchyk *et al.,* 2019; Ivanova *et al.,* 2022). The physical method of solarisation of soil with white plasma of 0.005-0.006 mm significantly reduces the number of larvae of plant parasitic nematodes. When using this method, a destructive temperature of 47-52°C is provided in the soil at a depth of 20 cm (Cunningham and Couey, 1986). Other mechanical and physical techniques that are peaceful for the environment include mulching, physical barriers, coatings. Mulching citrus plantations creates conditions for the normal development of beneficial insects and the destruction of weeds (Beloev *et al.,* 2020).

Biological control methods use the potential of natural agents that are specific, i.e., feed only on targeted parasitic organisms. Natural agents act relatively slowly, act by secreting secretions, and do not have the dramatic "killer effect" associated with chemical control (Maharramova, 2023). As a result, it takes time to establish biological control. However, when biological control is fully established and not interfered with, it is permanent, as natural agents self-renew and usually do not require further human intervention to ensure continued success in pest control. Natural enemies do not destroy parasitic organisms, but act in such a way as to reduce the number of parasites to a level that causes little damage to the plant (Papadopoulos, Katsoyannos and Carey, 2002). The number of natural enemies decreases after they have reduced the number of parasites. Using natural enemies in biological control is very simple and inexpensive for farmers. This is because biological control is either natural or developed by international/regional agricultural research institutions that serve communities through governments.

Chemical methods of exposure have their own specifics. Pesticides should be used in conjunction with the previously mentioned control measures and only when the parasite population density causes economic damage or when environmental conditions contribute to the disease. Selective insecticides are products that primarily target parasites that need to be controlled, with little or no harmful effects on most beneficial parasites (Shahini *et al*., 2008; Shukurova and Shukurlu, 2022). If the use of pesticides is considered appropriate, a selective product should be selected if possible. Selective insecticides typically retain biological control agents, reduce the risk of secondary pest outbreaks, reduce the environmental impact, improve farm security, and minimise the number of applications required (Panfilova *et al.,* 2020). Broad-spectrum insecticides should only be used if there are no other practical ways to control parasites. Synthetic pesticides are used

on demand and often only during a certain period of the parasite's life cycle. In addition, the method of genetic resistance of host plants is successfully used, which involves the use of genetically resistant plants to avoid or minimise plant losses caused by insects, pests, or pathogens (Danilenko *et al.*, 2021; Pfeiffer *et al.*, 2007).

As part of the experiment, the following results were obtained. Based on monitoring the dynamics of this very dangerous pest, convergence is considered important in the implementation of integrated protection programs for high-quality production, with maximum respect for the environment. However, it is necessary to properly implement methods that help identify and diagnose the Mediterranean fruit fly in order to intervene at the most appropriate time, using appropriate control tools for *Ceratitis capitata*. One of the main results of this field test was the diagnosis of the pest, as the main element of the effectiveness of control (Tables 1-7).

Table 1: The number of flies caught in Med Fly Stick traps

Monitoring dates	*The number of flies per trap*					*Sum*
	Trap 1, Med Fly Stick trap	*Trap 2, Med Fly Stick trap*	*Trap 3, Med Fly Stick trap*	*Trap 4, Med Fly Stick trap*	*Trap 5, Med Fly Stick trap*	
15.08.2019	-	-	-	-	-	-
20.08.2019	-	-	-	-	-	-
25.08.2019	-	1	1	-	-	2
01.09.2019	2	3	1	2	2	10
05.09.2019	3	5	3	4	4	19
10.09.2019	3	6	3	4	4	20
15.09.2019	4	6	4	5	4	23

Note: Traps were placed on 09.08.2019 in Xarrë.

Table 2: The number of flies caught in Med Fly Stick traps

Monitoring dates	*The number of flies per trap*					*Sum*
	Trap 1, Med Fly Stick trap	*Trap 2, Med Fly Stick trap*	*Trap 3, Med Fly Stick trap*	*Trap 4, Med Fly Stick trap*	*Trap 5, Med Fly Stick trap*	
15.08.2019	-	-	-	-	-	-
20.08.2019	-	-	-	-	-	-
25.08.2019	-	-	-	-	-	-
01.09.2019	1	-	-	-	-	1
05.09.2019	2	1	1	1	-	5
10.09.2019	3	2	1	1	2	9
15.09.2019	3	2	1	2	2	10

Note: Traps were placed on 10.08.2019 in Mursi.

Table 3: The number of flies caught in Med Fly Stick traps

Monitoring dates	*The number of flies per trap*					*Sum*
	Trap 1, Med Fly Stick trap	*Trap 2, Med Fly Stick trap*	*Trap 3, Med Fly Stick trap*	*Trap 4, Med Fly Stick trap*	*Trap 5, Med Fly Stick trap*	
17.08.2019	-	-	-	-	-	-
22.08.2019	-	-	-	-	-	-
26.08.2019	1	1	-	-	-	2
03.09.2019	2	1	2	1	-	6
08.09.2019	2	3	1	2	2	10
14.09.2019	3	3	2	3	3	14

Note: Traps were placed on 12.08.2019 in Konispol.

Table 4: The number of flies caught in Med Fly Stick traps

Monitoring dates	*The number of flies per trap*					*Sum*
	Trap 1, Med Fly Stick trap	*Trap 2, Med Fly Stick trap*	*Trap 3, Med Fly Stick trap*	*Trap 4, Med Fly Stick trap*	*Trap 5, Med Fly Stick trap*	
15.08.2019	-	-	-	-	-	-
20.08.2019	1	1	1	-	-	3
25.08.2019	3	1	2	2	1	9
01.09.2019	5	2	3	3	3	16
06.09.2019	6	3	3	4	4	20
14.09.2019	2	1	3	2	1	9

Note: Traps were placed on 10.08.2019 in Xarrë.

Table 5: The number of flies caught in Med Fly Stick traps

Monitoring dates	*The number of flies per trap*					*Sum*
	Trap 1, Med Fly Stick trap	*Trap 2, Med Fly Stick trap*	*Trap 3, Med Fly Stick trap*	*Trap 4, Med Fly Stick trap*	*Trap 5, Med Fly Stick trap*	
17.08.2019	-	-	-	-	-	-
26.08.2019	-	-	-	-	-	-
03.09.2019	1	-	2	1	-	4
08.09.2019	2	1	3	3	2	11
15.09.2019	3	2	3	4	3	15

Note: Traps were placed on 11.08.2019 in Konispol.

Table 6: The number of flies caught in Med Fly Stick traps

Monitoring dates	*The number of flies per trap*					*Sum*
	Trap 1, Med Fly Stick trap	*Trap 2, Med Fly Stick trap*	*Trap 3, Med Fly Stick trap*	*Trap 4, Med Fly Stick trap*	*Trap 5, Med Fly Stick trap*	
15.08.2019	-	-	-	-	-	-
20.08.2019	2	3	2	4	1	12
25.08.2019	2	2	1	3	2	10
02.09.2019	4	3	5	6	4	22

Monitoring dates	*The number of flies per trap*					*Sum*
	Trap 1, Med Fly Stick trap	*Trap 2, Med Fly Stick trap*	*Trap 3, Med Fly Stick trap*	*Trap 4, Med Fly Stick trap*	*Trap 5, Med Fly Stick trap*	
16.09.2019	6	8	7	10	11	42

Note: Traps were placed on 10.08.2019 in Vrrinë.

Table 7: The number of flies caught in Decis traps

Monitoring dates	*The number of flies per trap*				*Sum*
	Trap 1, Decis trap	*Trap 2, Decis trap*	*Trap 3, Decis trap*	*Trap 4, Decis trap*	
16.08.2019	2	1	3	2	8
21.08.2019	3	2	2	4	11
25.08.2019	1	-	2	-	3
30.08.2019	5	7	3	6	21
05.09.2019	7	9	7	8	31
10.09.2019	8	7	6	4	25
14.09.2019	2	4	1	3	10

Note: Traps were placed on 11.08.2019 in Xarrë.

Analysing tables 1-7, the following can be noted. The effectiveness of the mass trapping technique is determined not only by the properties of traps or attractants in the trap, but also by the ratio between the flight dynamics tracked by sex pheromones and the time when traps are placed. The placement of Med Fly Stick traps is guided by this scientific basis. Med Fly Stick traps were installed on several farms, where their placement density was 50/ha. To verify the effectiveness of the trap, flies caught in 5 traps were counted during each demonstration test. Compared to the dynamics of swarming, the capture intensity of the Med Fly Stick traps was higher, starting from the 10th of September. In all demonstration tests, Med Fly Stick traps were able to catch Mediterranean fruit flies during the entire production period without compromising their trapping properties. Another important aspect that has been confirmed was the purity of the fruit, which was not affected by the larvae of the Mediterranean fruit fly (*Ceratitis capitata*). Based on the fact that mass trapping methods reflect different efficiencies, a test was also conducted using the CeraTrap (Decis Trap), which proved to be effective in protecting production. From the results obtained in the presented evidence, the following conclusions can be drawn:

1. Based on monitoring the dynamics of numbers through sex pheromones (Trimedlure), for the first time it was possible not only to identify the pest under study, but also to monitor the dynamics of the pest's swarming. This suggests that attention to the pest under study, a very dangerous pest that requires a large number of chemical treatments to keep below the economic level of damage, should be focused in the second half of August.
2. For the first time in the conditions of Albania, the method of mass trapping using Med Fly Stick and Decis Trap traps was applied, which effectively functions when trapping this pest. However, this technique may not work in all regions. Therefore, it is necessary to evaluate the effectiveness in various ecological and climatic conditions.

3. Analysis of products in experimental fields showed no damage to larvae of the Mediterranean fruit fly (*Ceratitis capitata*).
4. Use of this technique guarantees the invulnerability of citrus fruits from this pest, allows controlling it without the use of insecticides, which directly affects the benefit of clean from chemical residues of production, as the main requirement for food safety.

Based on the fact that this pest is a constant threat to citrus fruits, and to finally eradicate this pest from the study area, this study suggests to:

1. Increase the duration of monitoring the dynamics of the population of this pest from 1 year to 2-3 years, to obtain a final conclusion about the dynamics of swarming.
2. In order to have definitive data on the effectiveness of the mass trapping method, it is necessary that this control method is applied for 2-3 years (These suggestions are based on biological aspects).
3. Evaluate the effectiveness of each of the Med Fly Stick and Decis Trap traps used in the mass trapping method for the conditions of Albania.

Conducting tests in this form will not only increase farmers' confidence in mass trapping techniques, catching optimal prerequisites for the transition to pest eradication on the territory, but also awareness of the feasibility of mass use of this technique by farmers.

Discussion

The results of the study position the phenomenon of integrated management as a basic element of the system for effective implementation of the concept of sustainable agricultural management. As seen from the findings of researchers, in particular Abdel-Razek and Abd-Elgawad (2021), integrated pest management is a systematic and coordinated approach to pest population management, which is positioned as a convergence of the potential of various methods and practices for preventive protection, timely identification, and effective control of pest populations. This approach combines various strategies, such as physical and mechanical barriers, biological control, live traps, and only if absolutely necessary – chemical means.

Considering the current situation in the region with populations of *Ceratitis capitata* described in this study, the necessary transformation of the existing management system in the field of population control is necessary. Contemporary researchers in relevant scientific areas, in particular Xia *et al.* (2021), confirm that one of the most effective tools for optimising the situation is the active use of modern tools of integrated technologies. Khfif, Mokrini and Sbaghi (2022) also pointed to the need to develop effective tools for integrated management processes to maximise the potential of interaction between modern innovative solutions and conventional agricultural practices. According to Luck, Morse and Moreno (1986), the priority and main weight of integrated pest management is to reduce the dependence of agricultural production on chemicals. At the same time, the researchers note, that one of the main advantages is the minimisation of the use of pesticides, which allows mitigating the risks of environmental pollution, ensuring the protection and preservation of biodiversity, and preventing the occurrence of pest resistance to common chemicals.

However, individual researchers, in particular Suárez *et al*. (2024), emphasise the obvious intensification of pest management efficiency through integrated management, arguing for such conclusions by the possibility of using a combination of different methods and strategies, which leads to greater efficiency in pest control. According to the researchers, the optimal combination of biological and physical methods creates a reliable barrier against the spread of pests. In addition, the integrated pest management method contributes to the conservation and rational use of resources (water, soil, pesticides), since within the framework of the studied approach, pest populations are controlled as accurately as possible and in the least practical areas (Easa *et al.*, 2024). Following some researchers, including Zavala-López, Marte-Diaz and Martínez-Pujols (2021), such a concept should offset the phenomenon of imbalance in the area in the aspect of financial feasibility. The researchers characterise the definition of integrated pest population management as a means of reducing costs. It is worth agreeing with researchers, because despite the cost of implementing integrated management systems at the initial assessment, in the long term this approach allows minimising the cost of chemical pesticides and other vectors of costs for levelling the consequences of pest populations.

In the process of implementing the analytical part of the study, a close relationship was established between the level of integration of monitoring processes and the effectiveness of the environmental safety system. The conclusions confirm the feasibility of integrating a significant part of management processes in the field of pest control (Havryliuk *et al.*, 2022; Lahlali *et al*., 2021). According to Giunti *et al.* (2023) and Abbas *et al*. (2021), the main goal of the integrated management process in the field of agriculture and environmental sustainability is the accumulation, protection, and optimal use of natural resources. The researchers emphasise, that insufficient access to modern technologies and innovative solutions for organic management and lack of readiness for their practical implementation are the most significant factors limiting the potential of integrated management in the field under study. Ensuring the safety of agricultural products involves the implementation of an effective policy to minimise chemical exposure to soils and plants and maximise the greening of pest control processes (Miloslavić *et al.*, 2012; Nabiyev *et al.*, 2024). Such conclusions correspond to the results of the current study in the aspect of positioning an integrated approach as a single effective solution in the process of transformation of the agricultural management system.

The results of the current study lead to conclusions about the need to ensure effective interaction between bodies of different levels of management, society, and business involved in agricultural production, towards implementing integrated approaches to pest management. Current scientific position of Boulahia-Kheder (2021) and Plá *et al*. (2021) synergises the proposed approach in the aspect of forcing the positive dynamics of the process of transformation of the management paradigm in the field of convergence of effective management and ensuring environmental safety. According to the researchers, integrated pest management helps maintain public health. Using fewer chemicals minimises the risk of poisoning for humans and biodiversity. Abd-Elgawad (2021) identifies specific prerequisites for the development of an effective pest management system and the basis of an integrated approach, focusing on the need for an appropriate resource base and the readiness of farmers for dynamic changes. The researcher suggests that it is possible to ensure high efficiency of integrated management of pest populations using economic methods, while noting that the process is inversely dependent, since the

economic and environmental spheres of activity have determining factors of mutual influence. The current study proved that the maximum results in the area under study can be achieved as a result of the convergence of efforts of individual farms to monitoring the state of land and environmental indicators in general.

The actualisation of the issue of integrated pest management is intensifying in parallel with the trend of increasing dependence of agricultural efficiency on the management decision system, and in this context, the principle of environmental safety should form a top priority. Sustainable management in an unstable environmental situation has significantly expanded the scope of its functioning, confirming the effectiveness of implementing innovative technological solutions and optimisation opportunities in most areas of life (Yerzhanova *et al.,* 2021). Yazid *et al.* (2020) focus on the vector nature of integrated management in agriculture, the need to develop effective mechanisms and implement comprehensive measures to prevent the destruction of soils, water resources, and biodiversity. Following the researchers, integrated pest management is positioned as a basic modern tool in the system of controlling the use of pesticides, which successfully combines efficiency with the principles of environmental sustainability. Abandoning outdated and tedious approaches in the agricultural management system in favour of integrated management helps to ensure the proper level of product safety, contributes to the preservation of resource potential, and encourages the sustainable development of the industry (Kryvenko, 2024; Shumka and Apostolou, 2018).

Additionally, Elimem *et al*. (2022) propose using the potential of integrated pest management technology within organic production, revealing its functionality in the aspect of increasing the economic efficiency of "green" production, creating safe and reasonable agricultural territories, optimising the handling of chemical protection products. In addition, the study highlights priority areas for targeted investment, which enhances the environmental sustainability of integrated management systems. The researchers emphasise the absence of potential negative consequences for the environment in the proposed concept. According to the researchers, national agriculture development strategies should provide for synchronisation with green development concepts. The authors agree with these findings, because the results of the current study confirm the effectiveness of integrated solutions in the process of pest control, monitoring environmental parameters, and greening agricultural production.

Despite significant scientific achievements in the field of integrated pest management as a basis for developing environmental sustainability, the issue of their large-scale practical adaptation to the realities of Albania remains unresolved. The development of an innovative approach to the management paradigm in the field of agricultural management in the concept of convergence of the most effective technologies of biological protection, tools and methods for optimising the industry towards sustainable development is considered promising.

Conclusions

The study of the current state of the pest population management system in the region under study on the example of *Ceratitis capitata* determined the prospects for optimising the industry in the context of green sustainable agricultural development. In the process

of analysing the opportunities, challenges, and benefits of the proposed integrated management concept, the risks caused by the process of transformation of rural land due to pesticide pollution, depletion of the natural resource base, and the uncontrolled nature of soil, water environment, and landscape pollution were identified. It was established that the success of levelling the negative consequences of eco destruction is determined by the state of implementation of integrated agricultural management technologies, and this industry needs urgent optimisation. In the course of the study, the potential for integrated management of the Mediterranean fruit fly on citrus plants in the Konispol region was analysed using innovative approaches. As part of this objective, the dynamics of the Mediterranean fruit fly population were studied using Trimedlure bait traps.

As a result of the experiment, it was found that the effectiveness of the mass trapping technique is determined not only by the properties of traps or bait, but also by the ratio between the swarm dynamics tracked by sex pheromones and the time of placing traps. In all demonstration tests, Med Fly Stick traps were able to catch Mediterranean fruit flies during the entire production period without compromising their trapping properties. Another important aspect that was confirmed as a result of the experiment is the purity of the fruit, which is not affected by the larvae of the Mediterranean fruit fly (*Ceratitis capitata*). Based on the fact that mass trapping methods reflect different efficiencies, a test was conducted using the CeraTrap (Decis Trap), which proved to be effective in protecting production. Thus, based on monitoring population dynamics using sex pheromones (Trimedlure), for the first time, the presence of a pest was not only confirmed, but also the dynamics of pest swarm was monitored. Thus, it can be concluded that attention to this very dangerous pest, which requires a large number of chemical treatments to stay below the economic level of damage, should be focused in the second half of August. As part of the experiment, the first method of mass trapping was used in the country, using Med Fly Stick and Decis Trap traps, which effectively functions when trapping this pest. However, this technique may not work in all regions. Therefore, it is necessary to evaluate the effectiveness in various ecological and climatic conditions. The use of this technique guarantees the protection of citrus fruits from this pest, allows controlling it without the use of insecticides, which directly affects the benefit of clean production from chemical residues, as a basic requirement for food safety.

Based on the fact that this pest is a constant threat to citrus fruits, and in order to make the final eradication of this pest from this area possible, it is considered appropriate to monitor the dynamics of the population of this pest for 2-3 years to have a final conclusion about the swarming dynamics. It is also promising to evaluate the effectiveness of each of the Med Fly Stick and Decis Trap used in the mass trapping method for the conditions of Albania. Conducting tests in this form will not only increase farmers' confidence in mass trapping techniques, but help to finally eradicate this pest from this area as a result of awareness of the mass use of this technique by farmers.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*	*Author 6*
Conceived and designed the research or analysis	Yes	Yes	No	No	Yes	No
Collected the data	Yes	No	No	No	Yes	No
Contributed to data analysis & interpretation	Yes	Yes	No	Yes	No	No
Wrote the article/paper	Yes	No	No	Yes	No	Yes
Critical revision of the article/paper	No	Yes	Yes	No	No	No
Editing of the article/paper	Yes	No	Yes	No	No	Yes
Supervision	No	No	Yes	No	Yes	No
Project Administration	No	No	No	Yes	No	Yes
Funding Acquisition	No	No	No	No	No	No
Overall Contribution Proportion (%)	25	15	15	15	15	15

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This study was compiled with financial support from USAID and implemented by AAC-Lushnja.

Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)
The author(s) solemnly declare(s) that this research has involved animal subject (body or organs) for experimentation. The research was based on field laboratory experiment involving fruit fly. Other contexts of animals were only indirectly covered through literature review. Therefore, an ethical obligation of ARRIVE applies and is appended.

Research on Indigenous Peoples and/or Traditional Knowledge
The author(s) solemnly declare(s) that this research has not involved Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were only indirectly covered through literature review. Therefore, prior informed consent (PIC) of the respondents or a Self-Declaration in this regard is not applicable for this article.

Research involving Plants
The author(s) solemnly declare(s) that this research has involved the plants for experiment and field studies. Some contexts of plants are also indirectly covered through literature review. So, during this research the author(s) obeyed the principles of

the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

Research Involving Local Community Participants (Non-Indigenous) or Children
The author(s) solemnly declare(s) that this research has not directly involved any local community participants or respondents belonging to non-Indigenous peoples. Neither this study involved any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

Competing Interests/Conflict of Interest
Author(s) has/have no competing financial, professional, or personal interests from other parties or in publishing this manuscript. There is no conflict of interest with the publisher or the editorial team or the reviewers.

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The ARRIVE guidelines 2.0: author checklist

The ARRIVE Essential 10

These items are the basic minimum to include in a manuscript. Without this information, readers and reviewers cannot assess the reliability of the findings.

Item		Recommendation	Section/line number, or reason for not reporting
Study design	1	For each experiment, provide brief details of study design including: a. The groups being compared, including control groups. If no control group has been used, the rationale should be stated. b. The experimental unit (e.g. a single animal, litter, or cage of animals).	a. Mass capture of Mediterranean fruit fly population (Ceratitis capitata) via attractive glue traps (Med Fly Stick) and CeraTrap (Decis Trap). b. Mediterranean fruit fly population
Sample size	2	a. Specify the exact number of experimental units allocated to each group, and the total number in each experiment. Also indicate the total number of animals used. b. Explain how the sample size was decided. Provide details of any *a priori* sample size calculation, if done.	a. The number of flies caught in Med Fly Stick traps in Xarrë was 131, in Mursi - 25, in Konispol - 62, in Vrrinë - 86. The number of flies caught in Decis traps in Xarrë was 109. b. The calculations were done manually, depending on the number of fliys that were caught.
Inclusion and exclusion criteria	3	a. Describe any criteria used for including and excluding animals (or experimental units) during the experiment, and data points during the analysis. Specify if these criteria were established *a priori.* If no criteria were set, state this explicitly. b. For each experimental group, report any animals, experimental units or data points not included in the analysis and explain why. If there were no exclusions, state so. c. For each analysis, report the exact value of *n* in each experimental group.	a. No criteria were set. b. Not reporting as no fly caught in trap was exluded. c. Not reporting as value of n wasn't identified.
Randomisation	4	a. State whether randomisation was used to allocate experimental units to control and treatment groups. If done, provide the method used to generate the randomisation sequence. b. Describe the strategy used to minimise potential confounders such as the order of treatments and measurements, or animal/cage location. If confounders were not controlled, state this explicitly.	a. Not reporting as randomisation wasn't used. b. The placement of Med Fly Stick traps is guided by this scientific basis. Med Fly Stick traps were installed on several farms, where their placement density was 50/ha. To verify the effectiveness of the trap, flies caught in 5 traps were counted during each
Blinding	5	Describe who was aware of the group allocation at the different stages of the experiment (during the allocation, the conduct of the experiment, the outcome assessment, and the data analysis).	The authors of the study and the farmers who owned the territory where the experiment was coducted.
Outcome measures	6	a. Clearly define all outcome measures assessed (e.g. cell death, molecular markers, or behavioural changes). b. For hypothesis-testing studies, specify the primary outcome measure, i.e. the outcome measure that was used to determine the sample size.	a. The effectiveness of the mass trapping technique is determined not only by the properties of traps or attractants in the trap, but also by the ratio between the flight b. Not reporting as it was not a hypothesis-testing study.
Statistical methods	7	a. Provide details of the statistical methods used for each analysis, including software used. b. Describe any methods used to assess whether the data met the assumptions of the statistical approach, and what was done if the assumptions were not met.	a. Not reporting as no statistical method was used. b. No assumptions of the statistical approach were made.
Experimental animals	8	a. Provide species-appropriate details of the animals used, including species, strain and substrain, sex, age or developmental stage, and, if relevant, weight. b. Provide further relevant information on the provenance of animals, health/immune status, genetic modification status, genotype, and any previous procedures.	a. Recent estimate of the number of host plants or potential host plants of the Mediterranean fruit fly, Ceratitis capitata, identified 353 species. b. Not reporting as none of it was studied.
Experimental procedures	9	For each experimental group, including controls, describe the procedures in enough detail to allow others to replicate them, including: a. What was done, how it was done and what was used. b. When and how often. c. Where (including detail of any acclimatisation periods). d. Why (provide rationale for procedures).	a. To detect the presence of the pest in citrus plantations and to track the dynamics of its population, the female sex pheromones Trimedlure b. As for the placement of traps to implement the mass trapping technique, they were placed during the first 15 days of August. in the outer part of the crown and c. The study was conducted in Konispol during 2019 on fields planted with citrus fruits, Clementine variety, with an area of 1 hectare. This village is located in the d. The purpose of the study was to analyse the potential of integrated management of the Mediterranean fruit fly on citrus plants in the Konispol region using innovative
Results	10	For each experiment conducted, including independent replications, report: a. Summary/descriptive statistics for each experimental group, with a measure of variability where applicable (e.g. mean and SD, or median and range). b. If applicable, the effect size with a confidence interval.	a. In all demonstration tests, Med Fly Stick traps were able to catch Mediterranean fruit flies during the entire production period without compromising their trapping properties. Statistics and a measure of b. The effect size with a confidence interval is not applicable.